URBANIZATION OF URBAN AGRICULTURE IN VERTICAL FARMING

ABSTRACT:

Urban agriculture, particularly vertical farming, is emerging as a sustainable solution to meet the growing food demands in densely populated urban cities. Vertical farming utilizes limited spaces such as rooftops and building interiors to cultivate crops, making it ideal for space-constrained environments. However, challenges like air pollution, soil contamination, and changing climate conditions pose serious threats to crop health and productivity.

This project focuses on enhancing vertical farming practices in urban areas through real-time environmental monitoring. Using advanced sensors such as PM2.5, CO2, and NOx, the system detects harmful pollutants and chemical levels in the air and soil. These sensors are integrated with the STM32H755ZIQ Nucleo development board, which features a dual-core STM32H755ZIT6 microcontroller combining a high-performance Cortex-M7 and a power-efficient Cortex-M4, suitable for advanced embedded applications.

By continuously monitoring air quality and soil conditions, the system supports precision farming, enabling farmers to make data-driven decisions that optimize resource use and improve crop yield. This project aligns with India's growing urban agriculture sector, which is expected to expand at a CAGR of 4.6% between FY20 and FY26. Ultimately, this solution promotes sustainable food production, better environmental management, and higher crop yields in urban vertical farming systems.

INTRODUCTION:

As urban populations continue to grow, traditional agricultural methods are becoming increasingly unsustainable in densely populated cities. This has led to the emergence of vertical farming, an innovative method that involves growing crops in vertically stacked layers, often integrated into urban buildings or controlled environments. However, despite its potential, vertical farming faces challenges such as maintaining consistent air quality, soil/substrate conditions, and microclimate control within enclosed spaces.

To address these challenges, this project introduces a Smart Environmental Monitoring System built around the STM32 Nucleo microcontroller platform, designed specifically for vertical farming applications. The system provides real-time, accurate monitoring of key environmental parameters: Soil Moisture, CO_2 concentration, and PM2.5 levels, all of which are critical for healthy crop growth in confined, soil-based or hydroponic systems.

In vertical farms, where various irrigation amounts may be applied to each plant layer, soil moisture monitoring is crucial. By avoiding both under- and over-watering, the analog soil moisture sensor, which is coupled via the STM32's ADC interface, aids in maintaining ideal hydrationlevels. Monitoring of CO2 Concentration: Photosynthesis in plants depends on CO2. External influences may cause CO_2 levels in closed vertical farm systems to surge or fall below optimal levels. This system makes sure that CO_2 levels are within the ideal ranges for plant productivity by using a digital CO_2 sensor (such as the MH-Z19) via UART.
PM2.5 Air Quality Monitoring: Poor indoor air quality can hinder plant growth and make plants more susceptible to disease, particularly in repurposed buildings or contaminated metropolitan areas. By monitoring airborne particulate matter, a PM2.5 sensor (such as the PMS5003) enables prompt ventilation or filter modifications.

LITERATURE REVIEW:

The rising global food demand, alongside rapid urbanization, has prompted a notable transition towards urban agriculture, with vertical farming recognized as a viable sustainable approach. This method entails cultivating crops in vertically stacked layers, frequently utilizing soil-less or controlled environments integrated within urban settings. The effectiveness of vertical farming is heavily reliant on the meticulous regulation and monitoring of environmental conditions.

1. Smart Agriculture and Environmental Monitoring

A variety of studies have investigated the application of embedded systems and sensor technologies in the agricultural sector. In the work of Patel et al. (2019), an automated irrigation system was introduced, utilizing microcontrollers and soil moisture sensors to decrease water usage on farms. Likewise, Jain and Verma (2021) highlighted the significance of sensor networks for tracking temperature, humidity, and soil conditions, which can enhance crop productivity and reduce waste. These studies illustrate the promise of affordable, microcontroller-driven systems for agricultural monitoring, providing a solid foundation for your STM32-based solution.

2. **Vertical Farming Environmental Challenges**

Research conducted by Despommier (2013) pointed out that vertical farms necessitate accurate control of CO_2 levels, moisture, light, and temperature to create optimal growing conditions. Conventional greenhouses

and indoor farms often lack effective real-time feedback mechanisms, leading to inconsistent growth outcomes.
Our project aims to fill this void by integrating real-time air quality and soil data collection, which is crucial for optimizing closed-loop vertical farming systems.

3. Air Quality Monitoring in Agriculture
The impact of CO_2 and PM2.5 sensors on plant health has been widely researched. Li et al. (2020) demonstrated that elevated CO_2 levels, up to a certain threshold, can enhance photosynthesis, but exceeding this level may yield negative effects. Additionally, Majeed et al. (2022) noted that airborne PM2.5 particles can hinder leaf gas exchange and adversely affect plant health.

EXSISTING METHOD:

In previous method they have just brainstormed idea about detecting the parameters like Temperarture, Soil pH and rainwater sensing. But they just created as prototype but they didn't analyse the real time data.

- Sensor Deployment Without Real-Time Processing: Sensors for soil moisture, temperature, and nutrients were deployed, but no system was implemented for real-time data processing and automated responses.
- Data Collection Without Immediate Action: Environmental parameters like PM2.5, CO2, NOx, and soil quality were monitored, but the collected data was not used for real-time adjustments in agricultural practices.
- Lack of Automated Decision-Making: While irrigation efficiency techniques like drip irrigation and rainwater harvesting were considered, no AI-based system was implemented to optimize water usage dynamically based on real-time data.
- No Real-Time Analysis for Pollution Impact: Although air pollution parameters were recorded, there was no real-time analysis or adaptive mitigation strategy to protect plant health.
- Absence of a Continuous Monitoring System: The study focused on measuring environmental factors, but no continuous monitoring system was implemented to provide real-time insights or alerts for farmers.

PROPOSED METHODOLOGY:

To develop an intelligent air quality monitoring system to detect pollutants and chemicals that affect plant growth in urban agriculture. Our strategy introduces an essential element by tracking air quality in real-time, which has a direct impact on urban crop development.

- Air Quality Sensor -PM2.5 Sensor - Measures small particles that can affect photosynthesis.
- CO2 Sensor – Detects excessive CO2 levels that may impact plant respiration.
- NOx Sensor – Monitors nitrogen oxides, which can be harmful to crops.
- Implementation Strategy Sensor Calibration and Integration - Connects the sensor to the accuracy of the STM32 and test data.
- Data Processing and Storage - Store real-time data for trend analysis and insights.
- Communications Module - Send real-time data to cloud-based systems for remote monitoring. The user interface is to develop a panel of farmers panels to access contamination levels and recommendations.
- Testing and Optimization - Optimization based on deployment and outcomes in urban farm conditions. Expected BenefitsEarly detection of harmful contaminants affecting crops.
- Real-time alerts and recommendations for city urban farmers. Improvement of decision - making and sustainable agriculture. Evolution - can be extended using additional sensors (for example, soil quality, humidity).

PARTIAL RADING:

Time (s	Soil Moisture (ADC	CO2 Level (ppm	PM2.5 Level (µg/m³
0	600	450	80
1	590	460	85
2	580	455	90
3	610	470	88
4	620	480	87
5	605	490	86
6	600	500	85
7	615	495	84
8	610	485	83
9	620	480	82

PARTIAL GRAPH: